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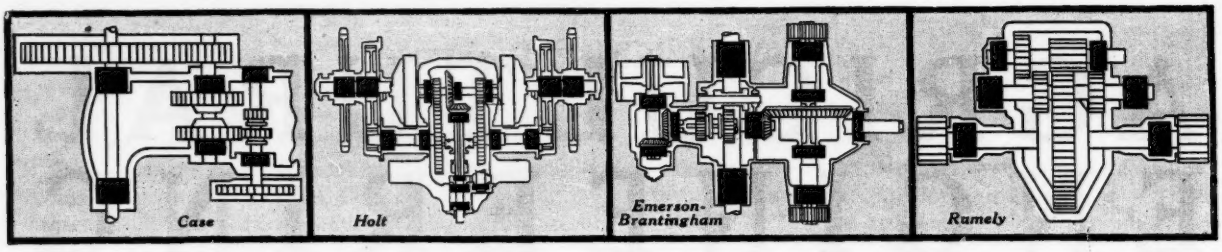

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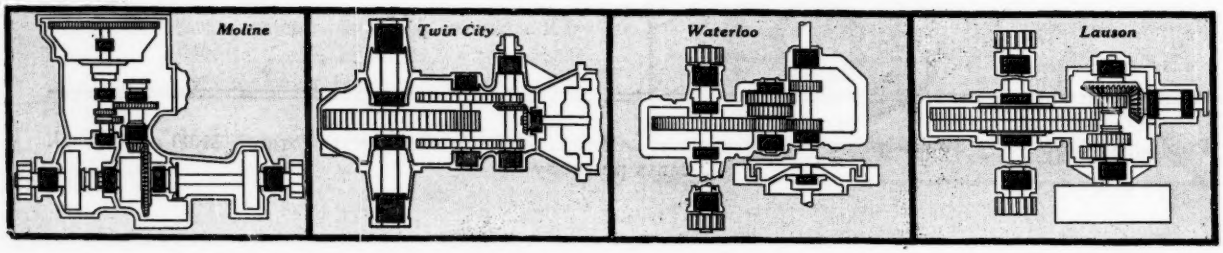


Climatic Dairy Barns

By W. B. Clarkson [1] and C. S. Whitnah [2]

EVERY part of the United States has experienced freezing weather at some time during its history; even the most southern points in Florida, Texas and California have not entirely escaped.

The U. S. Weather Bureau has issued an outline map of the United States showing graphically the lowest temperatures ever observed in the history of the bureau. In the study of this map, one is confronted with some startling records showing the wide extent of low temperature weather conditions during winter.

When it is realized that points so far south as Columbia, South Carolina; Mobile, Alabama; Vicksburg, Mississippi; Shreveport, Louisiana; Waco and El Paso in Texas, are within the zone of a possible zero temperature in winter, we can then understand the importance of a careful study and analysis of the housing conditions for stock in the Southern States as well as in the North.

The varying climatic conditions of this vast territory extending from the Gulf of Mexico as far north as dairy cattle are handled is a more important factor in sanitation than the average stockman realizes and the handling of domestic animals for profit is one of the most important and immediate problems confronting the agricultural engineer.

In the necessarily limited scope of this article, we can touch upon the dairy barn only, but what is said of it will apply in a large measure and with equal force under certain modified conditions to all farm buildings where livestock is handled.

In the dairy barn, we find by comparison that the cow, which produces the largest percentage of butterfat per calories of food consumed plus the cost of handling is the animal of greatest profit and in the production and maintainance of such an animal, every surrounding condition ought to be taken into consideration and carefully analyzed for the purpose of utilizing every element of advantage and, as much as possible, eliminating the disadvantages.

The animal husbandry departments in the various agricultural colleges for many years have been developing the science of breeding, feeding and management and the Agricultural Engineers in their department of the work, must keep pace with this development.

CLIMATIC FARM BUILDING ZONES

In the study of farm building ventilation and the many problems that confront the student, one of the most important considerations is the minimum temperature likely to be encountered, but in the practice of farm building construction very little thought has been given to the correct planning of the ceiling, walls, windows and doors as these are related to the various climatic conditions during the winter months.

Fig. 1, shows an outline map [3] of the United States and the southern portion of Canada. It will be noted that on this map, lines have been drawn to indicate the boundary lines between the four zones. The first zone embraces the provinces of Manitoba and Saskatchewan and part of the provinces of Alberta and Ontario as well as parts of the states of Montana, Minnesota and the entire state of North Dakota.

The second zone is clearly defined on the map and it is interesting to note that this line curves down into the state of Pennsylvania, taking in that portion of the state where the temperature in winter reaches a lower degree than in the balance of the state, this section properly belongs to the second zone. It will be noted also that this line is drawn around a section of northwestern Washington and eastern Idaho, which belongs to the second zone. There is a portion of the state of Wyoming, clearly defined on the map, that is first zone territory.

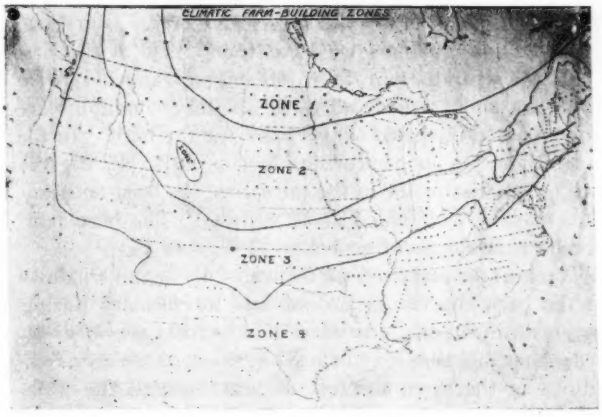


Fig. 1

The boundary lines of these zones have ben determined after a careful study of weather bureau reports. As near as we are able to determine, the first zone embraces a territory where the temperature will drop as low as thirty degrees below zero during the winter months. A

[1] King Ventilating Co. Mem. Amer. Soc. A. E.
[2] King Ventilating Co. Jun. Amer. Soc. A. E.
[3] The map was revised by the U. S. Weather Bureau.

sustained temperature as low as minus twenty degrees is not an unusual occurence in the southern portion of the first zone with a drop of fifty degrees in the northern portion of that zone. In the southern portion of the second zone, we find that a sustained low temperature from zero to twenty degrees below is not unusual.

The territory embraced in the third zone by the same analysis will experience a sustained low temperature between zero and ten degrees above. The northern portion of the fourth zone, especially on the western side, quite often experiences storms or blizzards in which the temperature extends below zero and in this territory a good barn is a profitable investment.

THE HEATING PLANT

In the dairy barn the heating plant is the herd of cattle housed therein. Each cow is a radiating unit of that plant. The B. T. U. of heat given off by a dairy cow must be as the calories of food and water consumed is related to her bulk and the amount of her milk flow. The proportion of food used in the manufacture of milk and that part given off in heat is problematical but we can be sure that if the barn room is kept clean, the air fresh and the temperature of the air controlled at a degree that causes the cows to be contented and happy, it follows naturally that the milk flow will be increased. If, under such conditions, their milk flow increases and there is a proportional decrease in the heat given off, then the most important problem for the agricultural engineer seems to be, *not how much heat* is given off by the cow but to determine *the most efficient use of this heat.*

In our observations we have found that in the first zone a temperature of 35 to 40 degrees above zero in the stock room, where all other sanitary conditions are good, is a comfortable temperature for the herd. In the second zone a temperature as low as 40 to 45 degrees will be practical while in the third zone the barn temperature may be maintained at 50 degrees. The barn temperature should never go below 33 degrees F.

The heat passing through the walls, doors and windows of the barn constitutes a dead loss to efficiency during these months of the year when cold weather prevails. In order that this heat may be used to produce sanitary conditions in the barn, the loss of heat through the walls and ceiling must be reduced as much as possible.

Having given proper consideration to temperature conditions where the barn is located and the best temperature for the barn room, our task is to determine the amount of heat given off into the atmosphere by the heating plant, the cow, and then design the barn and the ventilating system to make the most efficient use of this heat.

The amount of heat given off by the cow in a dairy barn must be computed in order to determine what type of barn wall and capacity of ventilating system will make the most economical use of the heat given off. The heat that is given off from the body of the cow, goes into the air and outside through the barn walls and up the ventilating flues.

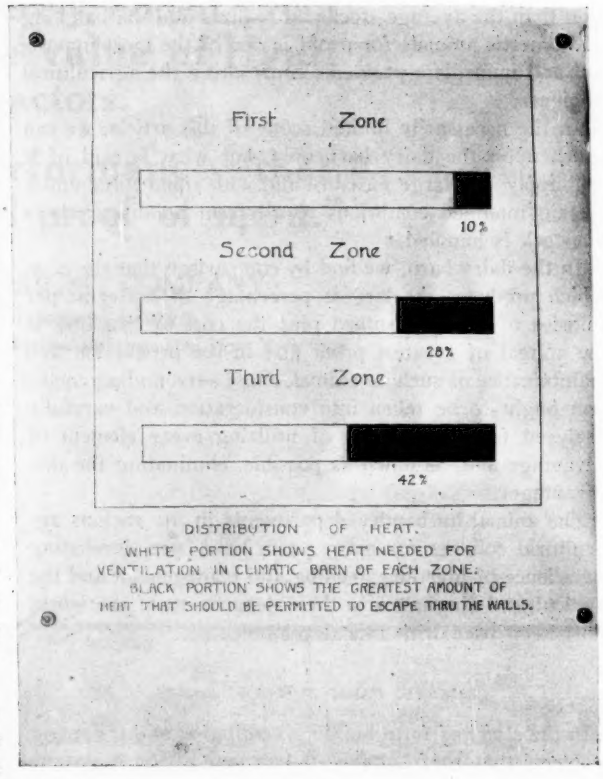
Pending the receipt of a report, which we are expecting from Dr. H. P. Armsby, giving his computations of the heat generated by the cow through metabolism, the method we have used to determine the heat given off by the dairy cattle is to compute the amount of heat lost through the walls of the barn and the amount of heat used by the ventilating system to provide a circulation of air. The amount of heat lost through the barn walls, windows and ceiling may be computed as follows:

$$H = [(W \times K_w) + (D \times K_a) + (S \times K_s) + (C \times K_c)] \times [T—T.]$$

H = heat in B. t. u.
W = window area in sq. ft.
D = door area in sq. ft.
S = side wall area in sq. ft.
C = Ceiling area in sq. ft.
k = coefficient of heat loss in B. t. u. per sq. ft. per degree.
t = temperature inside.
t' = temperature outside.

The amount of heat in the air going up the foul air flue is as follows:

$$H = v \times A \times d \times s \times (t—t')$$



DISTRIBUTION OF HEAT.
WHITE PORTION SHOWS HEAT NEEDED FOR VENTILATION IN CLIMATIC BARN OF EACH ZONE.
BLACK PORTION SHOWS THE GREATEST AMOUNT OF HEAT THAT SHOULD BE PERMITTED TO ESCAPE THRU THE WALLS.

FIG. 2

H = heat in B. t. u.
v = velocity in flue feet per hour.
A = area in flue and sq. ft.
d = density of air at temperature at bottom of flue.
s = specific heat of air.
t = temperature of air at bottom of foul air flue.
t' = temperature outside.

By this method we have arrive at approximate values of the amount of heat given off by dairy cattle.

Tests of temperature conditions in a number of dairy barns show that the amount of heat given off by a herd of cattle is very nearly constant for cattle of a given size in a given climate. This heat comes from the feed of the cows and must be used economically if the cows are to derive the greatest benefit from the feed.

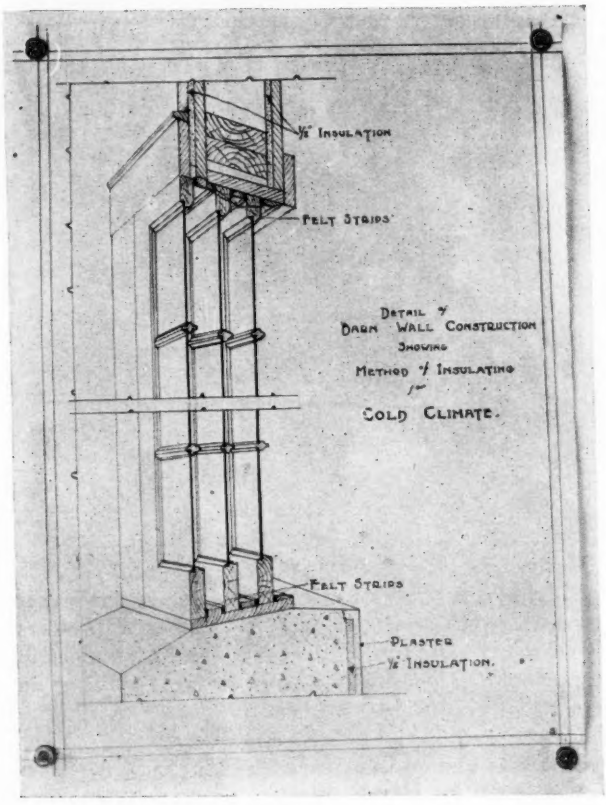


FIG. 3

A ventilating system will make the most efficient use of the heat by drawing the fowl air from near the floor, it is then taken out at the lowest temperature existing in the barn.

The fowl air flues should be of large enough area to carry out sufficient air to ventilate the barn properly with the flow of air resulting from the circulatory movement of the warm air in the barn and the pressure head caused by the passage of wind across the ventilator.

The heat that is given off by the cattle is also made use of in the ventilated barn because of the increased capacity of the air to carry off moisture.

DISTRIBUTION OF HEAT

In order to maintain a standard of purity of 96.7% of air that has not been breathed, it is stated by Prof. King[4] that it will require an air movement of 59 cubic feet per minute, per cow. It will take a quantity of heat to warm this amount of circulating air which will vary with the difference between the temperature in the barn and that outside. In each climatic zone then a certain percentage of the heat is required for proper ventilation. The barn should be constructed so that the heat loss through the walls is within the limit which will leave the heat required for proper ventilation. The chart shown in Fig. 2 represents the relative amount of heat, which is used by a ventilating system that circulates 59 cu. ft. of air per minute, per cow and lost through the walls of a barn of proper construction for the different climatic zones.

In such cases the barn room is assumed to have a cross-section 32 feet wide and 8 feet high in which the volume was 600 cubic feet per cow. This represents very nearly an average condition.

Taking as an average value 4000 B. t.u. per hour for the heat given off by a cow weighing about 1200 pounds, a reasonable weight for Holstein cattle, we find that about ten percent of this heat is the greatest amount that can be allowed to be lost and maintain a temperature of at least 33 degrees when the out side temperature falls to 30 degrees below zero.

In the second zone we have considered 33 degrees as minimum in the barn and in the third zone a 45 degree minimum, as this represents the condition when the greatest demand is made on the heating plant in the barn in the several zones.

WALLS FOR CLIMATIC DAIRY BARNS

In the light of the data already accumulated in our Research work and the first hand study of the actual conditions in various barns in all of these zones, we feel justified in presenting the detailed drawing illustrating the character of the wall which should be provided in all dairy barns, situated in the first zone.

We believe that the barn wall in this zone should have a coefficient of not greater than 16 B. t. u. per hour per degree difference in temperature. Fig. 3 shows a perspective of a lumber wall and details of a window, also a perspective of a concret wall and window detail. We are making no attempt in a limited scope of this article to discuss all of the materials that are available for barn wall construction but have simply taken two of the most popular materials in use as an illustration.

[4] "Ventilation of Dwellings, Rural Schools, and Stables," by F. H. King.

For the barn wall in the second zone, we suggest the character of a wall as illustrated in Fig. 4 and the coefficient for this wall is not greater than .43.

We have shown in Fig. 5 the character of a wall most suitable for a barn in the third zone. It is evident that the consideration of heat loss is not as important for a barn in this zone as is the control of air movement through the barn. For this reason the important consideration is to have the walls free from cracks and other air leaks.

We believe that the farmers situated in Oklahoma, the pan handle of Texas and perhaps all of the northern edge of the fourth zone will not make a mistake to have the same character of construction as in the third zone barn.

When we take into consideration that the dairy cow is a very nervous indivdual, and of a temperament that

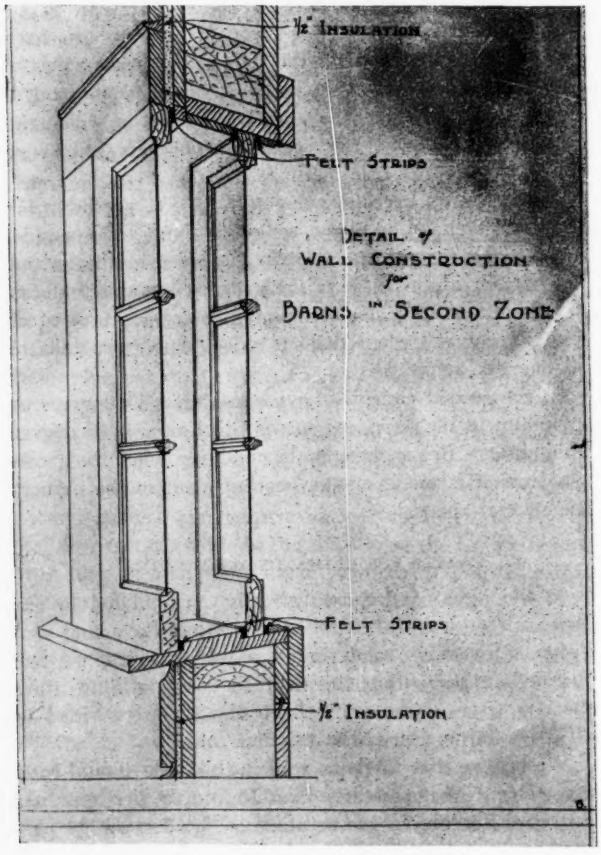


Fig. 4

is very susceptable to unusual conditions conditions, we believe that the dairymen in the southern states will find its very profitable to erect barns that are built tigh enough and with a properly installed ventilating system so that the temperature and air in the barn room in winter can be properly controlled, thus affording opportunity to keep the dairy herds comfortable, contented and happy during that portion of the year when the storms and blizzards are prevalent.

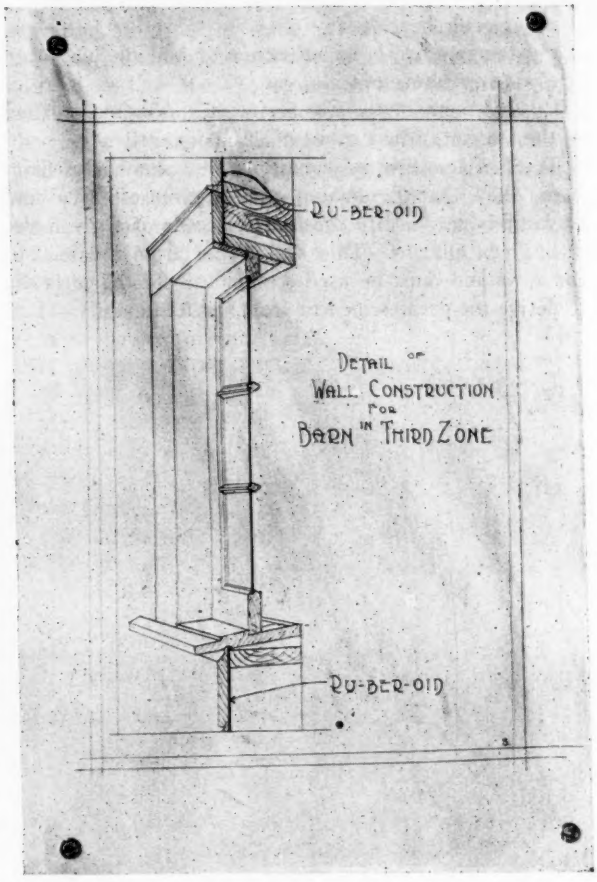


Fig. 5

In closing we call attention, that if the reader wishes to compare the results of our computations with others it will be necessary to consider the proably variations in temperature, rations and other differing conditions in order to draw a true comparison.

The organization of a Section of the A. S. A. E. on the Pacific Coast is now very promising. The membership has increased in the western states in the last few months to a remarkable extent and this connected with the problems related to agricultural engineering in these states, power farming being one special problem, makes it fitting that such an organization should exist.

R. H. Driftmier has accepted a position as professor of farm machinery and farm structures at the Kansas State Agricultural College at Manhatton. Prof. Driftmier is a graduate of Iowa State College in Agricultural Engineering and is well qualified to handle this work.

Agricultural Engineering in Farm Buildings

By W. A. Foster [1]

THE growing scarcity of building materials and the increasing cost of skilled labor has brought the farm building industry into the range of the agricultural engineer. New types of construction were necessary to conserve materials; new materials were brought into use as substitutes for materials which are growing scarcer. More economical planning was required to reduce labor in functioning; greater use of sunlight and ventilation was sought. The greatest efficiency was necessary to properly utilize the maximum stresses in materials. These requirements drove the carpenter out of the designing field and sought the trained designer. One who knew materials, construction, stresses, agricultural methods, and understood labor, was demanded.

The architect was not equipped; he was trained in construction, materials, stresses, and knew labor, but he was not familiar with agricultural conditions and methods, and furthermore, he did not care for this class of work because of the low fees for service and lack of transportation facilities. He was thoroughly trained in design for cathedrals and public buildings and knew planning for the city house and apartment. Since he did not know agricultural conditions and methods and did not seek small clients, he was not available.

On the other hand, the agriculturist was not accustomed to the use of plans and patterned his buildings after his neighbors. The farm press became one of the mediums through which the pioneering was done. The agricultural engineer came to the rescue. He was trained in materials, construction, and stresses, knew both agricultural conditions and methods, and he understood labor.

The old timber frame structure was satisfactory when materials were abundant and labor cheap. When the native timber supply was diminishing and transportation became a large factor in building, new types of construction were developed. At first, built up timbers were made of plank which was found costly, and the mow space was spoiled by posts, beams, and braces. Several new types of construction were developed. The Shawver truss came into use in the middle west and the Flickinger was used in the east. The self-supporting roof or wing-joist construction was later developed and recently the bent rafter gothic has come into general use.

As the farmstead was developed and economic conditions improved for the agriculturist, more specialized buildings were needed for the farm. The general barn, which sheltered all the animals, gradually gave way to buildings designed specially for the need. The horse barn, cattle barn, dairy barn, hog house, poultry house, and cribs were built on a different plan, giving attention to details which were formerly not considered. Light, ventilation, drainage, and sanitation became a part of the structure. The value of light, particularly sunlight, became known and structures were built for the greatest efficiency in sunlight. In the early days light was needed to assist in doing the chores. Its value as a sanitary element was either unknown or else not thought worth while.

The Iowa Sunlight hog house and its many modifications have considered sunlight. The public has been converted and sunlight is today an essential in hog-house construction. Only the greatest efficiency of sunlight can be secured by proper location of windows.

Ventilation has a place in modern buildings. It was not needed in the barn with the board roof or in the straw shelter with open side on south or east. Tight walls and close-fitting doors and windows have replaced the open walls. Fresh air must be supplied to replace the moist breathed air in buildings which shelter both man and beast.

The hog house, poultry house, barn, and farm house need ventilation. Considerable has been done along this line, but much remains undone.

Our forefathers selected a building site which was both high and dry. The surface drainage was not necessary and aerial drainage was not considered. Today both are important and demand proper consideration in selecting a building site and in designing a building.

The use of power has changed crib and granary design. The cribs may be high and filled without the backache of shoveling from wagon into bin as our fathers and many of us knew a few years since.

The development of the Iowa silo at the Iowa station brought out a new material, hollow blocks, for silo construction. This use introduced hollow blocks to the farmer as a building material. In recent years this material has become popular as a material in farm buildings. It improves the appearance; it makes a warmer construction because of the air spaces; it requires no upkeep in painting, and it is considered a permanent construction.

In farm house design many factors enter, such as utility, class of farming engaged in, number in family,

[1] Specialist in farm structures, Iowa Experiment Station. Mem. Amer. Soc. A. E.

location, climate, size of farm, nearness to town, and many others. Cost and appearance also enter into the plan and design. The former is self-assertive while the latter is many times neglected. We need better farm houses, better to function and meet the requirements of the owner, more efficient for the work of the farm woman and children and more comfortable for rest, recreation, and sleep.

In all the agricultural engineer is necessary in farm buildings. Greater production is encouraged. The acreage under cultivation is necessary under power farming, larger yields are harvested due to conservation of soil and better agricultural methods, larger bins will be needed to hold the harvests, more barns are necessary to shelter the stock and forage, more shelters for implements and power machinery. The agricultural engineer will be the determining factor in both planning and designing farm buildings and the development of new construction for many years to come.

Chimney and Fireplace Construction

By R. S. Whiting *

THE preponderance of fires reported as being caused from defective flue construction greatly emphasizes the necessity for more and greater care in the construction of chimneys. It has been made plainly apparent from investigations of the causes of fires, that the proper construction of chimneys, particularly with regard to their proximity to wooden frames and finish, has been carelessly if not maliciously overlooked.

No better means by which to prescribe the manner in which chimneys and fireplaces should be constructed can be had, than to quote from Chapter V of Standard Building Ordinances:

"CHIMNEYS AND FIREPLACES. Except as herein provided, all chimneys in every building hereafter erected, altered or rebuilt, shall be constructed of brick, stone or reinforced concrete. No masonry chimney shall have walls less than 8 inches thick unless is be lined on the inside with well burned terra cotta or fire clay chimney tile set in Portland cement mortar, in which case the wall shall be not less than 4 inches thick. The lining shall be continuous from the bottom of the flue to its extreme height.

Every smoke flue contained in a chimney hereafter erected shall have an area of at least 64 square inches, except that terra cotta flue linings 7 inches by 7 inches rectangular or 8-inch diameter inside dimensions, may be used.

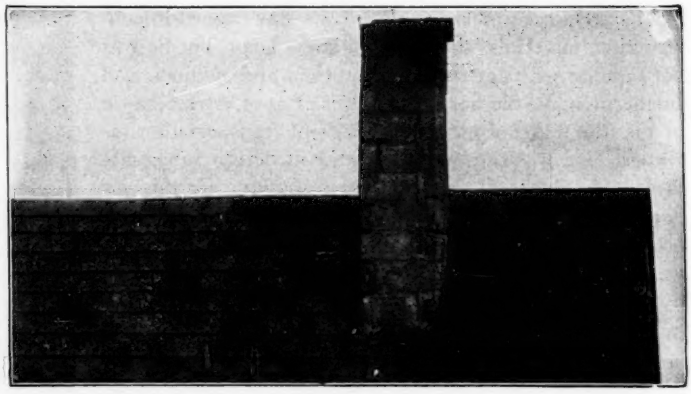


PLATE V

Chimney built with brick on edge and unlined. Roof in contact. Cracks in chimney under the roof, same as appear above it. The hazard is apparent.

PLATE VI

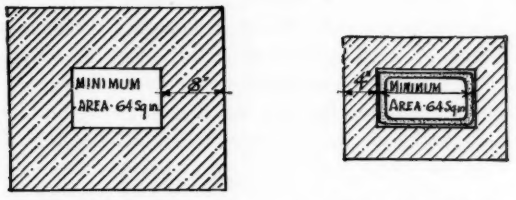
Chimney on wooden supports in a garret space. Walls one brick thick, unlined.

No chimney shall be corbeled out more than 8 inches from a brick wall, and such corbeling shall consist of at least five courses of brick. No one course shall project more than 1½ inches. See Plate IV.

Brick set on edge shall not be permitted in chimney construction.

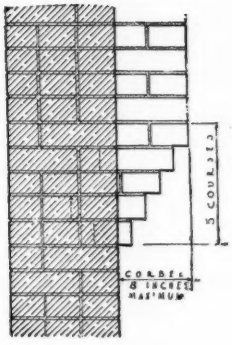
Chimneys of all low-pressure boilers, or furnaces, also the smoke flues for baker's ovens, large cooking ranges, large laundry stoves, and all flues used for similar purposes shall be at least 8 inches in thickness and be lined continuously on the inside with well-burned terra cotta or fire clay chimney tile set in Portland cement mortar. Chimney caps shall be terra cotta, stone concrete or iron.

[1] Architectural Engineer for the National Lumber Manufacturers Association. Mem. Amer. Soc. A. E.



Solid Masonry Brick with Flue Lining

Cross Sections of Flues
PLATE III



Corbeling
PLATE IV

The smoke flue of every high pressure steam boiler, and every appliance producing a corresponding temperature in a flue, if built of brick, stone, reinforced concrete or other approved masonry, shall have walls not less than 12 inches thick, and the inside 4 inches of such walls shall be firebrick, laid in Portland cement mortar for a distance of at least 25 feet from the point where the smoke connection of the boiler enters the flue.

All chimneys shall project at least 3 feet above the point of contact with a flat roof, or 2 feet above the ridge of a pitched roof.

Portland cement mortar only shall be used in the construction of chimneys their entire length.

No chimney in any building shall have wooden supports of any kind. Supports shall be incombustible and shall rest upon the ground or the foundation.

All chimneys which are dangerous from any cause shall be repaired and made safe, or taken down.

Metal smokestacks may be permitted for boilers, furnaces and similar apparatus where large hot fires are used, provided they have a clearance from all combustible material or not less than one-half the diameter of the

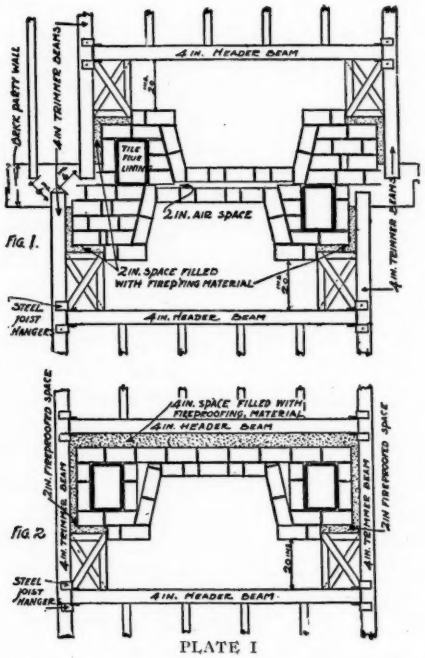


PLATE I

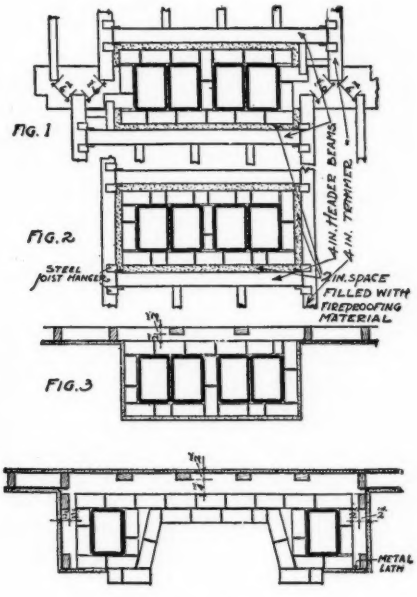


PLATE II

Fig. 1—Method of building two fireplaces back-to-back in a brick party wall to secure proper spacing between ends of floor joists. The space between backs can be filled if desired.
Fig. 2—Floor framing around a single fireplace. Note filling between framing and brickwork which serves both as insulator and firestop. } PLATE I

Fig. 1—Floor framing around chimney in a party wall to secure proper space between ends of floor joists.
Fig. 2—Ordinary floor framing around a chimney. All timbers 2 inches clear of brickwork and space filled with fireproofing material.
Fig. 3—Stud partition across back of a chimney showing proper method of arranging studs.
Fig. 4—Stud partition across back of a fireplace and around the ends of the chimney breast, showing proper method of arranging studs. } PLATE II

stack, but not less than 15 inches unless the combustible material be properly guarded by loose fitting metal shields, in which case the distance shall be not less than 12 inches. Where such a stack passes through a roof, it shall be guarded by a galvanized iron ventilating thimble extending from at least 9 inches below the underside of the ceiling or roof beams to be at least 9 inches above the roof, and the radius of the ventilating thimble shall be at least 18 inches greater than that of the smokestack. Metal smokestacks shall not be permitted to pass through floors.

The fireback of every fireplace hereafter erected shall be not less than 8 inches in thickness of solid brickwork, nor less than 12 inches on stone lined with firebrick. When a grate is set in a fireplace a lining of brick at least 2 inches in thickness shall be added to the firebrick; or soapstone, tile or cast iron may be used, if solidly backed with brick or concrete.

All flue-holes when not in use shall be closed with tight-fitting metal covers.

Ashes shall be kept in metal or other incombustible receptacles provided for the purpose. When the ash pit is located in a basement or cellar, enclosing ways and cover shall consist of at least 4 inches of brick or concrete.

Flues to be cleaned. All flues in every building shall be cleaned and all rubbish removed, and the flues left smooth on the inside upon the completion of the building. Once each year all flues shall be properly cleaned from top to bottom.

The worst single cause of fires is the defective chimney and to overcome the tremendous losses sustained therefrom, it is essential that architects, engineers, contractors and building superintendents should exercise extreme care, not only in proper design but also in the actual construction of all chimneys and flues.

Gothic Roofs for Barns

W. KIRKPATRICK [1]

ECONOMIC considerations have prompted or made necessary the evolution of the barn roof, of which the gothic type is a recent manifestation. Improved timber working machinery, problems of transportations and availability and the adoption of modern barn hay unloading tools are the principal factors influencing design in barn roofs.

In order to intelligently consider the theoretical merit or demerit of a barn hoof, it is necessary to have in mind its purposes and a familiarity with the relative importance of the things to be accomplished. As operating barn labor costs increase we may emphasize such construction as will permit maximum results from labor employed in filling or depleting the loft area. It is even probable that an overplus of rigidity might be sacrificed to make possible the filling of the loft area in part or whole, with stover, using air in compression as the vehicle. To accomplish this would require an elimination of roof members that would disrupt air currents in the area enclosed. First and maintenance costs and permanence are influenced by kind and quality of material employed, pitch of roof and manner of assembling. Utility only may not be sought. The barn or other farm buildings are prominent in the farmstead group, and while essentially buildings of manufacture or storage are a close part of the farm home enviroment, and lend or detract from its desire, ability and value, as they are visually attractive or otherwise.

In a study of the gothic barn roof frame we may confine our inquiry largely to the rafter member that gives the roof its contour and is its chief substance. Other factors of this roof are as in the older and better understood types, except that inflexible roofing of existing kind may not be applied in ordinary to gothic roofs having rafters not less than twenty-seven feet radius.

Two distinct types of gothic rafters are contemporary. The older type is a rafter commonly formed by assembling two or more pieces of 1x8 inch lumber, laminated by nailing. The members composing this rafter are worked to the specified radius before being assembled. This rafter in position in the roof, presents its convex surface and greater cross section dissention to overhead stresses. We are not presenting data in detail of this style rafter, for the reason that it is in ill favor with builders because of the laborious way in which the rafter members must be prepared. Power driven saws are not commonly available on the job for cutting the rafter members to conform to the rafter radius and the hand labor involved is of a kind and amount distasteful to mechanics. We find no published analysis of the stresses and resistance to this roof, but from casual examination we are inclined to believe it furnishes as commonly designed, the necessary rigidity and ability to bear snow and wind loads. It would seem that the excessive labor expense and loss of material coincident with this construction, has been cheerfully incurred by many builders because of the pleasing proportions of the finished structure. Now that the same contour is obtained by bending rather than sawing, interest centers in the so-called bent rafter method of forming the gothic roofs.

The superior appearance in popular regard, of the gothic roofed farm building, and the laborious way in which the old style gothic rafter was constructed, caused

[1] Manager Department of Farm Buildings, Gordon Van Tine Co. Mem. Amer. Soc. A. E.

builders to experiment with the bent and laminated rafter. The bent rafter because of alleged economy of material and labor is the one now usually employed. The word "gothic" applied to a style of architecture is a misnomer. The Goths created no architecture of their own. However, the use of the term to designate comprehensively the medieval architecture of north and western Europe of the period 1150 to 1500 A.D. has been so general that the

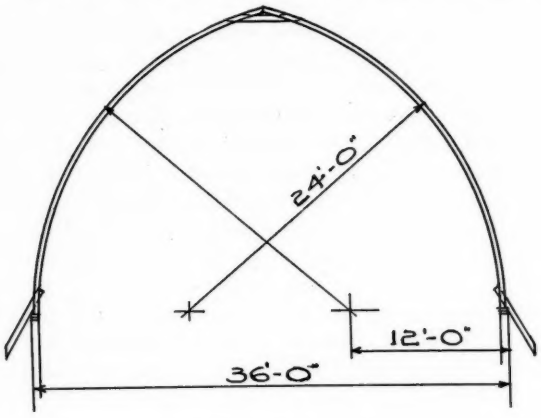


FIG. 1.

pointed roofed barn no doubt will be known as the gothic.

We find no archetype for the gothic. The term is applied broadly to forms of the semi-circular or those having a radius of two-thirds or more of the greatest breadth of the resultant arch.

There are two methods in common practice in determinating the pitch of gothic barn rafters. The first employs a radius equal to .666 of the greatest breadth of the span. Zero or pivotal point of the radius is in plane with the junction of plate and rafter, as in Fig. 1.

The second method employs a radius pivotal at the perpendicular at .75 of the span and on the horizontal in plane .125 of the arch span below finished plate level, as in Fig. 2. The roof pitches and areas resulting from the two radii used are only slightly dissimilar.

Many of the factors influencing barn roof construction of the gable or gambril type do not occur in the gothic. In ordinary barn roof framing, available timbers are of specified dimensions to which, for practical reasons, builders are confined. The gothic barn roof as commonly constructed, is peculiarly free of interior roof bracing timbers and its resistance to stresses depends to a marked degree, on the resistance of the rafters which are fabricated of random lengths of sound lumber three-fourths inches thick. It is apparent then that the rafter may without undue waste of material, conform to any radius within limits prescribed by convenience, appearance and factors of safety.

From a barn loft utility or operation standpoint, the more pointed roof shown in Fig. 2 presents a benefit that escapes casual scrutiny. The area of little value for storage in a barn loft is that bounded by the roof and a horizontal line drawn ten feet below the ridge. The loaded hay carrier requires from ten to twelve perpendicular feet in which to function, but it is the loft area below the carrier load level that is of most value. In practice the specified upper area of barn loft is little utilized for storage, so that it would seem best to restrict this area when opportunity presents. In Fig. 2 the loft area confined by a horizontal line drawn ten feet below the ridge is approximately thirty-two feet less than a corresponding segment in Fig. 1. Taking 448 cubic feet as the measure of a ton of partly settled hay, a difference in radius and pitch as noted in Fig. 1 and 2, is equivalent to a hay ton for each fourteen lineal feet of barn loft. To better visualize this comparison and get its practical significance, we may consider a gothic roof as projected in Fig. 1 as furnishing an excess of a little utilized area equivalent to five hay tons in a barn thirty-six by seventy feet.

RAFTER DETAIL

The span of the gothic barn roof varies with the horizontal cross section of the barn at outside plate level. It is being applied to barns of from sixteen to fifty feet in width. As no standard ratio of radius to span has been laid down, it is not possible to fix definitely the cross section dimensions of rafters for roofs of varying spans. Barns of twenty feet or more width are usually equipped with hay unloading machinery with a maximum lift of

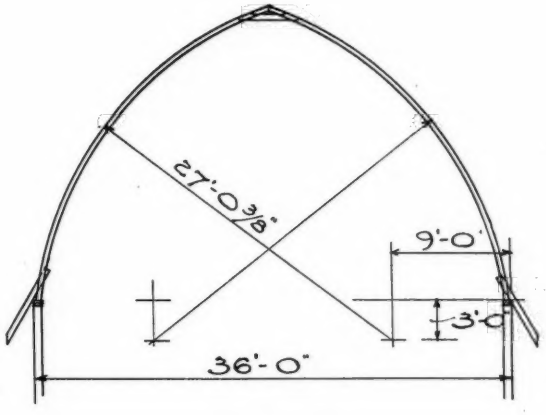


FIG. 2.

about 2000 pounds. The usual hay load on carrier and roof is about 500 pounds but infrequently it is much more, and 2000 pounds of loose hay has been raised from the wagon, elevated and deposited in barn mow at one operation. As there is opportunity under exceptional conditions, for the operation of hay unloading tools to put a 2000 pound hay load on the barn roof, it is then necessary to employ rafters of sufficient strength to carry

such loads even in barns of smaller size, that if not subjected to hay carrier loads, could employ lighter rafters.

Bent and laminated gothic barn rafters are commonly constructed of four or five pieces of 1x3 or 1x4 inch sound lumber S2S, of any kind generally employed in barn frames. Unsurfaced boards, because of greater frictional resistance would be preferable if they could be obtained in five-eighth or three-fourth inch thickness. Experiment discloses that per pound of nails used in laminating rafter members, the large nail secures most rigidly in the rafter. As the rafter member cannot be less in its greatest cross section dimension than that can be nailed without splitting, the minimum breadth then is that approximating three inches. Gothic rafters for barns less than thirty feet in width are commonly four pieces ¾x3 random lengths breaking joints two feet or more, well nailed and bolted three feet on center with three-eighth bolts, washered both ends. These rafters are placed two feet on center on the plate. For barns of thirty to thirty-six foot breadth, the rafters are commonly five ply ¾x4, on barns of thirty-six to forty foot breadth. The facility with which the gothic rafter can be proportioned to the stress is noticable.

In the central states, architects plans for bent rafter gothic roofed barns were first published in 1916. The pleasing appearance of these barns brot them quickly into favor, so that while a comparatively new design, there are many of them built. Such barns of this type as have been built having rafters projected as in Fig. 2, and subjected to wind and working stresses for a period of from one to five years, give indication of more than average permanence.

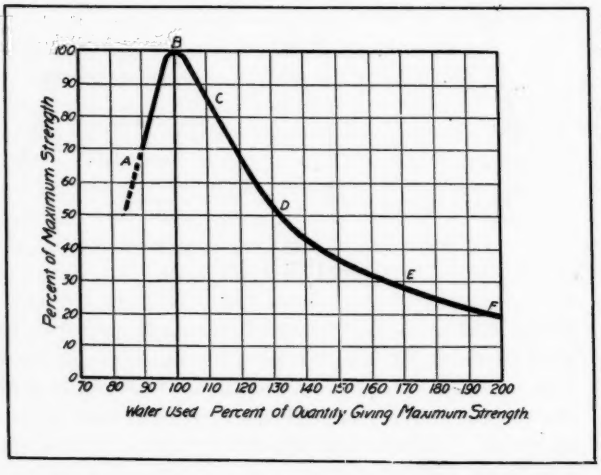
In the experiment of actual construction there have been obtained some interesting data in regard to bent wood construction. The force exerted by three-fourth inch thick lumber to resume its original position when bent as slightly as occurs in gothic rafters when the radius employed is twenty-one feet or more, is negliglible and may be disregarded as a factor in fractional stress analysis. The greater the moisture content of the board the more adaptable it is to a bent position and the more readily its fiber fixes in the changed position.

The theoretical efficiency and economy of the multiple member rafter is borne out by stress experiment and the further consideration that the narrow board usually can be had at less cost per board foot.

Effect of Water on Strength of Concrete

By W. G. Kaiser [1]

TESTS recently conducted at the structural material research laboratory, Lewis Institute, Chicago, prove conclusively that the amount of water used in making concrete bears a direct relation to the strength of the resulting concrete. Among some engineers there exists the erroneous impression that the amount of water used in a mixture bears little if any relation to the final strength. In the tests mentioned, it has been fully proven that the quantity of water used is of the very greates importance and that too much water is fully as bad as too little. Results of the tests made at Lewis Institute are shown graphically on the accompanying curve. The point B on the apex of the curve indicates the maximum strength obtained when the proper amount of water is used. This amount is given as 100 per cent. It will be noted that the addition of 10 per cent more water than the quantity required for maximum strength reduces the strength of concrete by about 15 per cent. Thirty per cent too much water diminishes the strength by one half. In a like manner the strength of concrete falls very rapidly when there is insufficient water.



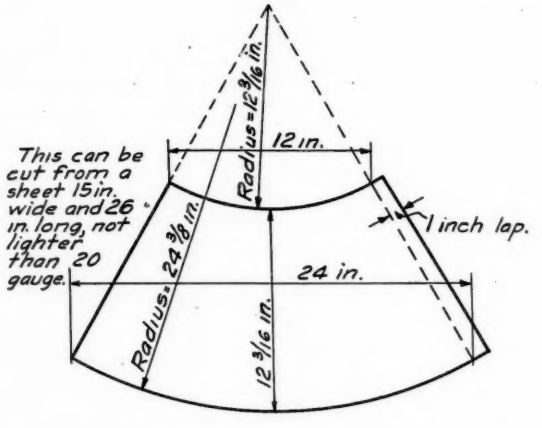
In practice it is seldom possible to produce concrete of a consistency which will give maximum strength, as the mixture would not contain enough water to make it readily workable under average conditions, especially in thin wall sections. Since the addition of a little extra water will produce a mixture that is workable, there has been a natural tendency to use too much water on some

[1] Farm and Cement Products Bureau. Portland Cement Association. Mem. Amer. Soc. A. E.

jobs, particularly where concrete is placed between forms and allowed to harden there. In the manufacture of concrete block where the mold is removed immediately, there is sometimes a tendency to use too little water.

A simple method of determining the proper consistency for a given concrete job is known as the slump test. It is now being specified and used by many engineers engaged in concrete construction. The apparatus for making the test is very simple and inexpensive. All that is required is a sheet metal tube 12 inches high, eight inches in diameter on the bottom and four inches in diameter on the top. This tube is placed on a table or some even surface with the large end down and filled flush with the concrete for which it is desired to determine the proper consistency. The concrete in the tube is thoroughly settled by agitating it with a pointed iron rod. The tube is then lifted off at once, care being taken to raise it vertically. As soon as the tube is removed, the concrete will of course slump, the amount depending upon the amount of water in the mixture. After one or two minutes have elapsed, the height of the pile is measured and the slump determined by subtracting this height from the original height of the pile, which in this case would be twelve inches. For pavements, floors and large foundations, the slump should not exceed three inches and for thin walls and thin watertight structures, it should not be greater than seven inches. In case of thin walls some of the strength of the concrete is sacrificed to secure a smooth and even surface.

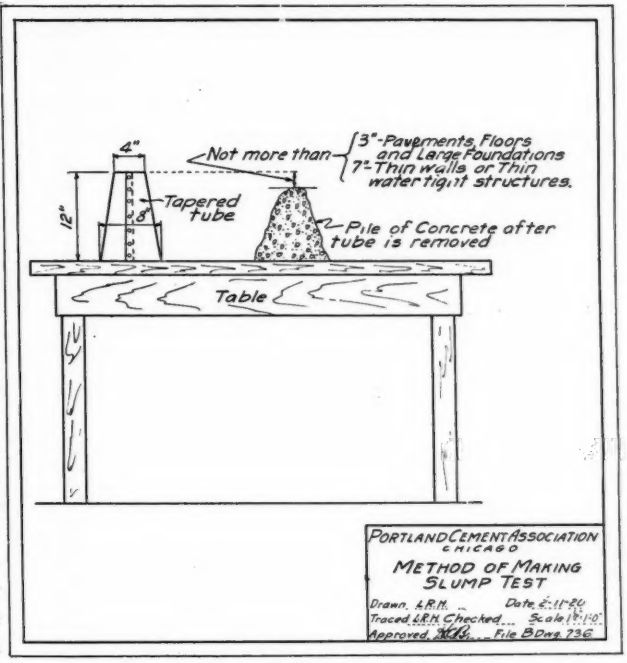
The amount of water which will yield the proper consistency with the average mixture is six gallons of water


This can be cut from a sheet 15in. wide and 26 in. long, not lighter than 20 gauge.
Radius = 12 3/16 in.
12 in.
1 inch lap.
Radius = 24 3/8 in.
24 in.
12 3/16 in.

A piece of metal of this shape will, when rolled up, make a tapered tube needed for the slump test illustrated on the preceding page.

to one sack of cement or, stating it in a different way, one and one-half gallons of water to one cubic foot of concrete in place. The correct amount of course varies with the character of the aggregate as well as with the proportions used. Some aggregates like sand stones are of a porous nature and will absorb considerable water, while others are practically non-absorbant. Some aggregates may contain considerable moisture before being introduced into the concrete mixture. This is particularly true of sand.

In general a good rule to follow is to use as little water as possible, which after thorough mixing, will produce a workable mixture suitable for the kind of work for which the concrete is intended. This will encourage the man at the mixer to keep the batch in the machine longer and produce stronger concrete.



The slump test here illustrated is a safe one for determining the right amount of water to use in the concrete. Detail of metal tube is shown on page opposite.

A preliminary meeting of those interested in the use of natural ground or calcined rock materials — lime, rock phosphate, gypsum, potash shales, etc.— as fertilizers was recently held at the Sherman Hotel, Chicago. The meeting effected a temporary organization with Mr. C. A. Tupper, president of the *International Trade Press*, as chairman, and Mr. H. H. McDonald, secretary of the Gypsum Industries Association, as secretary. The officers and the executive committee are to arrange for a meeting of national scope sometime in late December or early January, at which time a permanent organization is to be effected.

The Federated American Engineering Societies will hold a conference in Chicago, October 21. The A. S. A. E. has been invited to send a delegate to this meeting and President F. N. G. Kranich has appointed E. A. White to represent the society.

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A. S. A. E. Meeting at Chicago

Since it has been definitely decided to have the next annual meeting of the A. S. A. E. in Chicago, much attention is being given the program. Word from the chairman of the Committee on Local Arrangements, Mr. W. G. Kaiser, bears the information that the headquarters of the meeting will be at the Sherman Hotel.

Advanced information from the Committee shows that they are favorably inclined toward holding a banquet this year. The committee on local arrangements consists of Messrs. W. G. Kaiser, K. J. T. Ekblaw and E. A. White.

Watch for more news about A. S. A. E. meeting in the next issue.

A. S. A. E. Asked to Test Left Hand Plows and Disc Harrows

At the meeting of the Plow and Tillage Implement Department of the National Implement and Vehicle Association, September 16, 1920, manufacturers of plows and disc harrows expressed themselves as desiring accurate information regarding the relative merits of left and right hand plows and also the comparative utility of harrows equipped with cutaway and round discs.

Although the meeting resulted in the reinstatement of the left hand plows in two sizes, 12" and 14", the manufacturers went on record as desiring the ultimate elimination of all left hand plows, both riding and walking. In order to get accurate information as to the merits of the two a motion was adopted requesting the A. S. A. E. to make an investigation of the utility of the left hand plow as compared with the right hand plow and make a public report of the findings.

Although the majority of the members desired reaffirming the elimination of cutaway disc blades, some of the members thought it necessary to continue manufacturing the cutaway discs. Before their manufacture is stopped altogether they suggested to the A. S. A. E. that they conduct field trials comparing the relative merits of the two types of blades particularly as regard advantages to the farmer and considering the higher costs of cutaway blades and report their conclusions to the Agricultural Equipment Standards Committee.

Extract from a Letter Upon "What Constitutes Good Plowing?"

It is the object of this letter to create if possible a discussion of this subject, and in order simply to give a start to the discussion, find below one of the methods which are used in judging good plowing together with the percentages used in the case:

1. Straightness of furrow.....10
2. Covering the trash.....15
3. Uniformity of furrow.....15
4. Crowning, or flatness.....10
5. Pulverizing 30
6. Straightness of ends.....10
7. Continuity 10

Continuity is to be construed to refer to each furrow turned without noticeable breaks, that is, without being chopped up.

The crowning, or flatness, refers to the condition of the ground as left, and varies in the different sections according to what the individuals of these sections desire. The other points in reference I think are perfectly clear.

DOUGLAS L. ARNOLD
Chief Engineer Special Engineering, International Harvester Co., Gas Power Engineering Department. Taken from *Farm Implement News.*

Notice

The proceedings of the last ten conventions of the American Society of Agricultural Engineers can now be purchased at the following prices:

Per 11 volumes (ten conventions) for A. S. A. E. members $4.50
Per 11 volumes (ten conventions) for non-members $9.00
Per single volume (one convention) for A. S. A. E. members $0.50
Per single volume (one convention) for non-members $1.00

The publications include articles by well known men upon drainage, irrigation, sanitation, farm structures, farm machinery, tractors, stationary engines, along with committee reports upon farm building equipment, farm power, farm structures, farm building ventilation, roads, and education.

The supply is limited.

For orders or information, write Frank P. Hanson, Assistant Secretary A. S. A. E., Ames, Iowa.

Position Open

We are requested to announce a vacancy in the position of assistant professor of agricultural engineering at the Oklahoma Agricultural and Mechanical College, Stillwater, Okla. The salary, although not definitely fixed, will be $2,500 or better. All interested parties are asked to write Dr. H. G. Knight, director of the Experiment Station and Dean of Agriculture of this institution.

What Form will the Tractor Ultimately Take

By WILLIAM C. ZELLE[1]

IF I succeed in promoting a discussion amongst agricultural engineers on this subject, I shall consider this attempt to have been well worth while. A thorough discussion of this question by them should enlighten the automotive engineers very much on the features considered necessary in a general farm tractor, and therefore should be welcomed by the latter. On more than one occasion have I heard automotive engineers remark: "We know HOW to build a tractor but we do not know WHAT to build." It most certainly is the province of agricultural engineers to enlighten them on this subject.

I shall not only attempt to discuss features which appear to be desirable in a general farm tractor but some of the tractors and designs which have been on the market and which have disappeared entirely or nearly so, and the reasons, as I see them, for their disappearance.

Selling Price

Unquestionably it must be conceded that the selling price is of the utmost importance. The lower the price the more attractive to the farmer and therefore the greater the market. However, no matter how low the price, if that low price has been made possible by reducing the sphere of usefulness of the tractor, or by decreasing its durability and ease of operation, or by increasing its cost of operation or maintenance, that low price will not keep that machine on the market although it may place it there at the beginning. This question is very pertinent at this time because of the many tractors now on the market whose sole recommendation is a low price.

Power of Tractor

This is a question which must be settled for each particular farm. A farmer would do well to consult an agricultural engineer when determining what horse-power of tractor to buy. I here propose to discuss the tractors for the general farmer raising the crops to which are devoted the greatest acreages. These will run from an 8-16 HP. to a 16-32 HP.; with a much lighter demand for machines of greater power which will not be here considered.

Tractor Parts

I do not believe the farmer is vitally interested in the kind or makes of the different parts comprising the tractor. I do not believe he cares particularly what make or kind of radiator is used, whether the motor is a one, two, four, six, eight or twelve cylinder affair, or whether it is of vertical, horizontal, opposed or twin design. This does not mean that he is not interested in quality, economical performance, and having parts on the tractor which he considers essential to its proper, economical, and easy operation, for he most assuredly is. But it does mean particularly that he is interested in the design of the tractor — a design that will enable him to satisfactorily and economically perform as large a part as possible of the work he is now doing with work animals and portable engines.

Range of Work

To me this is by far the most important factor entering into the consideration of the tractor for the farmer's use. The more nearly the tractor completely replaces work animals and portable engines on the farm the more profitable and attractive will it prove to the farmer. The larger its sphere of usefulness, the greater the market.

The kinds of work now done on farms by work animals and portable engines are:

1. Breaking or plowing land.
2. Preparing the seed-bed, rolling, harrowing, etc.
3. Seeding the land.
4. Cultivating such crops as require it from the time they sprout until they should be laid by.
5. Harvesting the crops.
6. Belt work.
7. Hauling the crop to storage bins or to market.
8. Road building, ditching, general utility work, etc.

The cultivation of the crops requires a number of special features in a tractor, such as ample clearance, light ground pressure, a gauge that will enable the machine to get through the rows without injuring the crop, as short a turning radius as practicable, etc.

At this point the question naturally arises: Does the work of cultivation amount to enough to warrant the consideration of all of the features deemed necessary in a tractor in order that it may be used for this work on general farms? Referring to the *Monthly Crop Reporter*, issued by the U. S. Department of Agriculture, for July, 1920, we find the following:

TABLE NO. 1

Crop	*Acreage*
Corn	103,648,000
Wheat	53,652,000
Oats	41,032,000
Barley	7,437,000

[1] President Zelle Tractor Co., St. Louis, Mo. Mem. Amer. Soc. A. E.

Rye	5,470,000
Potatoes	3,849,000
Sweet potatoes	1,022,000
Flaxseed	1,706,000
Rice	1,345,700
Tobacco	1,859,700
Hay, tame	56,191,000
Cotton	35,504,000
Beans	834,000
Grain, sorghums	5,342,000
Peanuts	1,221,400
Broom corn	212,500
Sugar beets	978,500
Sorghum, sirup	401,600
Hops	29,700
Sugar cane	533,500
Total	322,269,600[2]
Total, without hay	266,078,600[3]

This table can be rearranged to show crops requiring plowing but no cultivation and those requiring both plowing and cultivation. The latter crops can again be subdivided into crops planted in rows of different widths:

TABLE NO. 2

	Crops Requiring No Cultivation	Crops Requiring Cultivation: Standard Rows 3'-4'	Narrow Rows Less Than 3'	Wide Rows More Than 4'
Corn		103,648,000[5]		
Wheat	53,652,000[4]			
Oats	41,032,000			
Barley	7,437,000			
Rye	5,470,000			
Potatoes		3,849,000		
Sweet Potatoes		1,022,000		
Flaxseed	1,706,000			
Rice	1,345,700			
Tobacco			1,859,700	
Cotton		35,504,000[6]		
Beans		834,000		
Grains, Sorghum		5,342,000		
Peanuts		1,221,400		
Broom Corn		212,500		
Sugar Beets			978,500	
Sorghum, Syrup		401,600		
Hops		29,700		
Sugar Cane				533,500[7]
Totals	110,642,700	152,064,200	2,838,200	533,500
Percentages, Exclusive of Hay	41.6%	57.2%	1.0%	0.2%

[2] This is considerably below the normal acreage devoted to these crops. This is probably due to the difficulty the farmer is experiencing in securing adequate help. This difficulty will be alleviated by a properly designed tractor.

[3] Hay receives no cultivation and very little plowing therefore it was not taken into account in the following table which has to do with crops requiring both plowing and cultivating. However, hay enters very largely into the question of the harvesting of crops.

[4] Back to about the pre-war acreage. The acreage in wheat in 1919 amounted to over 71,000,000 acres.

[5] The corn acreage has been reduced this year. The acreage in this crop for 1918 was over 113,000,000 acres.

[6] The cotton acreage is slightly reduced. It was in 1918 over 37,000,000 acres.

[7] The acreage devoted to sugar cane has again about reached that planted in the United States prior to the removal of the tariff which occurred about 1914. Cuba has increased its acreage in sugar cane to over 5,000,000 acres.

In other words, the crops requiring plowing but no cultivation occupy less than one-half of the total area devoted to all of the crops listed, whereas those requiring both plowing and cultivating occupy more than fifty per cent of the acreage.

An effort was made to learn what percentage of the farmers in the United States raised crops requiring cultivation and also what percentage of the land on their farms was devoted to such crops. There seems to be no available data in this matter. However, knowing that by far the greater number of farms of the South are very largely if not entirely devoted to the raising of both corn and cotton, and that both of these crops are raised as far north as climatic conditions will permit, for we raise corn in Michigan and cotton in Missouri, it seems safe to estimate that fully seventy-five per cent of all of the farmers in the United States raise some corn or cotton or other crops requiring cultivation.

Referring to *Farmers' Bulletin No. 719* and *No. 963*, issued by the U. S. Department of Agriculture, we find:

> The farmers from whom data for these *Bulletins* was secured had but forty per cent of their land in corn.
>
> They used the tractors but fifty days per annum.
>
> The acquisition of tractors made possible the elimination of but one-fourth of the horses formerly used.
>
> The horses had been employed one hundred days per annum.
>
> That the "peak load" in "hours of horse labor" was reached during the cultivating season for that corn and not during the plowing or harvesting season, as is so generally supposed.

This seems to indicate a duplication of "power plants" on these farms. There certainly can be no economy in such a state of affairs. And this condition applies to probably fully seventy-five per cent of all of the farmers in the United States.

Therefore it seems safe to conclude: 1st, From the standpoint of the total acreage devoted to crops requiring cultivation; 2d, From the large number of farmers raising such crops; and 3d, From the fact that the "peak load" in "hours of horse labor" on farms raising such crops comes during the cultivating season for those crops, that it is most decidedly worth while to consider the needs of a tractor to enable it to be used for cultivating such crops as well as to do the other work on these farms now being done by work animals and portable engines.

Referring to *Bulletin No. A-80*, issued by the U. S. Department of Agriculture, Bureau of Plant Industry, we find on page 5, a cut, figure 1, showing a cross section of a row of corn. This shows that the roots of that corn are almost at the surface at the stalk and have their greatest covering of earth midway between the rows. This same condition applies to cotton and other row crops.

Single row machines, that is, tractors able to pass be-

tween two rows and cultivate one row (or two half rows as it is frequently put by the farmer) would necessarily have to have their wheels travel near the stalks. This would probably result in cutting many of the roots and thereby decreasing the nutriment furnished the stalks by the roots and in that way decrease the yield. The soil is usually in a more or less plastic condition. The wheels passing over it will compact it, more or less, not only directly under the wheels but, because of the plastic condition of the soil, laterally. As the wheels travel near the stalk in single row machines this compacting would probably extend underneath the stalks where it could not be overcome by the cultivating implements following the wheels. The soil being compacted would make it more difficult for the roots to penetrate it, and they would probably do so to a less extent, thus again decreasing the amount of nutriment furnished the stalk and thereby further decreasing the yield. The single row machine would necessarily have to be narrow and it therefore would be unstable, readily upsetting or turning over. In all probability it would be equipped with wheels of small diameter which would make it difficult if not impossible to pass over rough ground and drainage ditches without upsetting or becoming stalled. On the whole it therefore seems safe to conclude that the tractor for the general farmer will not be a single row machine.

A number of machines have been placed on the market which straddled two rows and cultivated three rows at one passage of the machine. These tractors, as a rule, were stable, their wheels traveled mid-way between the rows, therefore if the wheels did compact the soil the implements following them readily overcame it. The wheels of these tractors were large, or the machines were equipped with crawlers, therefore they had no difficulty getting over rough ground or farm drainage ditches. With all of these sound features, however, the popularity of these tractors was very short-lived, and they have largely, if not entirely, disappeared from the market. Nearly all of them were large, requiring considerable space in which to turn around. This meant wider headlands or turn-rows, which meant an increase in unproductive land, or, if the roads were not widened, damaged crops in adjacent cuts. These machines were largely if not entirely of the three wheeled type which meant less accurate steering. Covering two rows of various widths it was necessary to make the outer wheels adjustable laterally. This reduced the rigidity of the machine and unquestionably increased the cost of maintenance. Furthermore the work of changing these wheels was more or less arduous. However, by far the most objectionable feature was the fact that the operator had to cultivate three rows at one passage of the machine. This is more work than one operator can attend to, and do the work properly. It seems to me that the latter objection is largely responsible for the disappearance of this type of machine.

Tractors straddling one row and cultivating two rows at one passage of the machine are on the market. Their wheels are large and travel midway between the rows. They are stable. They are fairly light in weight and therefore do not compact the soil to any serious degree. Any compacting that may be done can readily be overcome by the cultivating implements following the wheels. Straddling but one row the wheels do not have to be made adjustable laterally for a guage can be arrived at that will be but a few inches from the center of the rows or middles in any of the width rows these crops are normally grown in. Therefore the frame of these tractors can be made rigid, as far as the gauge is concerned, and therefore of simple design and construction. These tractors are almost one-half of the width of the three-row type, and usually much shorter. This enables them to turn around in a much smaller area. Two-row animal drawn implements have been on the market for some time. They can be considered an unquestioned success. I see no reason why a man cannot cultivate two rows at one passage of implements designed for that purpose when drawn by a tractor as well as he can when drawn by work animals. The tractors of this type are all, or practically all, of the two-wheeled type. They require the addition of a two-wheeled implement or a two-wheeled carrier to complete the machine and make it operative. This really makes them four-wheeled tractors for they are useless without the other two wheels. This leads to considerable duplication, for each implement designed for this type of tractor is required to furnish the other two wheels. While the selling price of the tractor part of this combination is in line with the selling price of other tractors of equal power, the ultimate cost, including a full line of implements or equipment, is very much greater than it need be. Because all of the weight is on two wheels it is not distributed as well as is possible where four wheels on the tractor itself are used. Because of the necessarily compact form of these tractors they are, I believe in every instance, provided with but one speed forward and one in reverse. This makes it necessary for the operator to consume as much time doing light work as in doing heavy work. Having but one speed, should the tractor become stalled at that speed, it is necessary to call for assistance in order to get out. I have heard this criticism made on a number of occasions about a very popular tractor of this type.

Therefore it seems safe to conclude that the tractor for the general farmer will be disigned to straddle one row while cultivating two rows at one passage of the machine; that, while the two-wheeled type is now quite popular, a four-wheeled tractor, doing away with the large amount of duplication of parts necessary with this two-wheeled type, will be found even more desirable and, in the end, less costly to the farmer.

Gauge and Clearance

Having concluded that the tractor will straddle one row while cultivating two, the gauge of the tractor would naturally be the average of the minimum and the maximum distances between the rows, since the wheels are not to be made adjustable laterally. Corn and cotton are normally grown in rows three to four feet apart, therefore the average distance between rows is forty-two inches. The implement manufacturers have adopted a gauge of forty-four inches for implements to cultivate corn and cotton crops, which is but one inch each way in each middle, which will still give ample clearance laterally, therefore the gauge adopted by them for tractors to be used for the same crops.

For clearance we can again turn to the implement manufacturers and benefit by their experience. They have determined that a center clearance of thirty-two inches is necessary for implements used in cultivating and *laying by* these crops at a time experience has indicated as proper for maximum yields. In lieu of other data we can adopt this as a minimum clearance for tractors for this purpose.

One or Two Men Per Tractor While Cultivating

Now we propose to replace the work animals with tractors. Tractors have no eyes — they must be guided constantly. We propose to increase the speed very materially. With it all we expect a single operator to do the work satisfactorily, work that, in the earliest stages of the crop, was frequently unsatisfactorily done at the slow speed and with the assistance of the eyes of the work animals. I am emphatically of the opinion that it cannot be done, especially so in the early stages of the crop. I'm sure that it cannot be done properly at the higher speeds proposed. I am sure that it would prove disastrous when the crop is young and tender. After the crop grows hardier it may perhaps be possible to devise some sort of fenders to assist the operator, but even then I question the wisdom of using but one man per machine for this work. The constant jerking of his head up in order to see to steer properly, and down again to look at the implements to be assured that they are doing their work properly and not injuring the crop would soon tire the operator so that he would have to quit or do slovenly work — all an added expense to the cost of cultivating the crop which to me appears greater than an additional man who shall give his undivided attention to the cultivating implements and the proper cultivation of the crop while the other man gives his undivided attention to properly steering the tractor.

I can hear the advocates of the "One Man Tractor" saying, "But what about the farmer who has no help — does all of the work himself," etc. He'll do what he always does do when he finds he needs help in order to derive greater profits from his farm or do work he cannot do alone. He'll find a neighbor in the same fix and they will arrange to help each other out, a very simple and logical solution.

Harvesting the Crop

This is one of the largest, if not the largest single items entering into the cost of producing crops. Every acre listed in Table No. 1 must be harvested, and the acreage devoted to hay is frequently harvested several times per annum. The cotton and tobacco crops, a part of the corn crop, and perhaps some of the other crops are still harvested by hand. But by far the majority of the harvesting is done with some form of harvesting machinery, such as binders, etc.

Practically all forms of harvesting machinery is designed with a cutter-bar, or some other harvesting device, extending to one side of the machine. The work animals are hitched ahead of the machine. Thus the power is ahead and the resistance to one side. This causes a slueing tendency, and frequently the machines do slue, especially so in heavy crops. The proper place, of course, would have been to have applied the power directly behind the point of resistance, which was impracticable. When tractors are used to replace the work animals on these machines the slueing tendency is undoubtedly aggravated.

With the cutter-bar to one side and to the rear of the operator it is impossible for him to keep his eyes constantly on it, whether the motive power is work animals or a tractor. As a result the cutter-bar is frequently run into an obstruction. When this occurs with work animals they feel the tug and stop, and as a rule no damage is done. Tractors, however, have no feelings, and, the resistance of the cutter-bar being insufficient to overcome the power of the tractor, it is broken. This puts the implement out of commission until it can be repaired or replaced, a serious interruption when harvesting.

While the pushing of implements is impracticable with work animals it is not so with a tractor. By properly attaching the implements to the tractor the weight of the latter can be used to hold the implement steady and against the work. Naturally, desiring to push an implement the first impulse is to fasten it to the front of the tractor. This has been done by several designers of harvesting implements which were brought out during the past year or two. From what I can learn these implements or attachments did very efficient work. To fasten them to the front of the tractor apparently a rather elaborate system of braces and connections was found necessary. The operator of the tractor, seated behind the steering wheel to the extreme rear end of the tractor, was naturally unable to see what the harvesting implement was doing or where it was going. Therefore an additional man was placed, in one case, on the radiator of the tractor, to look after the harvesting implement and

apparently to direct the tractor operator as to the course he was to steer. This arrangement does not appear to be particularly desirable.

If it is conceded that it is best to apply the power to the harvesting implement directly behind it and to push it rather than pull it, and it is also conceded that it is not desirable to attach the implement in front of the tractor, because of the objections cited above, then we have but one other solution and that is to attach the harvesting implements to the rear of the tractor and running the tractor backwards, or in reverse, thus pushing the implement. This arrangement has several very decided advantages. The tractor is already designed and built so that attachments may be fastened to the rear.

However, to efficiently and with ease push implements by running the tractor in reverse and pull them by running the tractor forward, the steering wheel will have to be so arranged that the operator can sit in front of it facing backwards, relative to the tractor, when pushing implements, as well as sit behind the steering wheel and facing forward, relative to the tractor, when pulling implements. This arrangement will enable the operator to face in the direction the tractor is moving and steer it in perfect comfort. By arranging the steering wheel in this manner and leaving it at the rear of the tractor the operator will have the implements directly before his eyes constantly, while giving his attention to steering the machine, because they will be in the line of travel of the tractor. This puts no extra strain on the operator and therefore the additional man needed when harvesting implements are fastened to the front of the tractor can be dispensed with. This saving thus effected each season will probably pay several times over any additional cost in building the tractor so that it can push implements when going in reverse and pull them when going forward.

Universal Central Control and Speeds

Granting that the tractor is to run in reverse when harvesting and forward when plowing or cultivating, and that it will have more than one speed in reverse and probably as many in one direction as in the other, makes it decidedly desirable to equip that tractor with a universal central control. By universal central control I mean an accessory, not absolutely necessary, but, as stated above, decidedly desirable, which will enable the operator to run the tractor, that is to manipulate it, as readily when pushing implements as when pulling them.

The tractor should always be equipped with an extremely slow speed of great power, a speed much slower than any normal working speed. This speed is to be used on heavy grades or in bad ground when the slowest normal working speed isn't sufficiently powerful to get the tractor with its load up the grade or out of a bad piece of ground. This speed might be referred to as the "trouble speed" and be fixed at this time at approximately one mile per hour.

The tractor should also be provided with a "Plowing Speed" — a speed where the draw-bar pull is sufficient to readily overcome the resistance, under the severest normal conditions, of the number of plows the tractor was designed for. This speed has been fixed, for the present at least, by the Society of Automotive Engineers, at two and one-third miles per hour for tractors having a draw-bar horse power of fifteen or less. This would cover the machines here under discussion. How long this rate, in fact any rate, will remain standard will depend on the degree of success met with my the many tests now being made by the advocates of higher speed plowing.

The power required to overcome the resistance of the ordinary cultivating implements is less than that required for plows when breaking land in the same soil; that is, the draw bar pull required for the cultivation of the crops is normally less than that required for breaking the same land with plows before planting the crops. Many advocates of two or more machines per former point to this fact as being in favor of their position, because a motor operates more efficiently and economically when working under its normal load. This is unquestionably true. However, the power is the draw-bar pull multiplied by the speed. Since the draw-bar pull for cultivating requirements is less than for plowing why not increase the speed when cultivating until the cultivating speed multiplied by the cultivating draw-bar pull equals the plowing speed multiplied by the plowing draw-bar pull, when the power requirements would be equal. This would not only permit the motor to be operated under the most efficient and economical conditions but it would also enable the tractor to cover much more of an acreage in a given time thus reducing the cost of that work. It may be argued that a speed for cultivating in order to use the full power of the motor would be too great to permit the operator to cultivate properly. That also is unquestionably true — when but one man is used for this work. However, we have already shown under "One or two men per tractor while cultivating" that it is highly improbable that one man can cultivate properly with a tractor under the ordinary speeds. With two men, however, one giving his entire attention to steering the tractor while the other gives his entire attention to the cultivating implements and the proper cultivation of the crops, this objection would probably be entirely overcome. In fact it is quite possible that better work would be done under those conditions, that is, at higher speeds with two men, because the work would be coming fast enough to demand their entire attention all of the time, thus giving them no opportunity to digress and get slovenly about their work. It may be assumed that the position here taken is inconsistent with the one advocating two men while cultivating. I do not think so, for, in advocating two men while cultivating, the matter objected to was the incessant changing of the work from that of steersman to that of

cultivator and back. This is what would unduly tire the operator, whereas here is advocated an increase in the same kind of work to a point where the hands and mind of both the steersman and the cultivator are so completely and thoroughly occupied that everything else is excluded. We all know that people do more efficient work when their hands and minds are constantly kept busy with that work. So far as I know no data has been published giving the draw-bar pull for plows when breaking land and for cultivating implements when cultivating that same land so we have no comparison by which a cultivating speed may be approximated that will permit the motor to be operated at its normal capacity. In lieu of better data we may suggest an increase of about fifty per cent over the plowing speed, or say, for the present, fix the cultivating speed at about three and three-quarter miles per hour.

It is very desirable, when going from one field to another, or when going to or from market or the home lot, *i.e.*, when there is no load or draw-bar pull on the tractor, to do so at the greatest speed possible, consistent with the comfort of the operator and the ability of the tractor to withstand the wear and tear. At this time this speed may be fixed at say about five miles per hour.

Summing up, we may fix, for the present knowledge of tractor speeds, the desirable speeds for a tractor for the general farmer, about as follows:

First, or "trouble seped," 1 mile per hour.
Second, or "plowing speed," 2.33 miles per hour.
Third, or "cultivating speed," 3.75 miles per hour.
Fourth, or "road speed," 5 miles per hour.

The position may be taken that so many speeds in reverse are not necessary. It will be shown under "Motor power for attachments" that there will be a decided advantage in having a number of speeds for harvesting implements, and, in accordance with the position here taken, this work is to be done with the tractor traveling in reverse.

Belt Work

Tractors should, of course, be equipped for belt work. Most of them, if not all, are so equipped with the proper gearing, clutch and belt pulley, so that power can be derived from the motor on the tractor for any farm equipment requiring same. The Society of Automotive Engineers has adopted certain speeds as standard so that not only tractor designers know what speed to give the belt pulley of the tractor, but designers of farm equipment, requiring power, can also be assured of having their equipment run at the proper speed for best results by giving that equipment a pulley of the right diameter to assure that proper speed. There is one point, however, which it seems might receive some attention. The pulley, to be effective and readily lined up with the pulley of the equipment to be driven, should extend beyond the frame of the tractor. This construction, while of advantage in lining up the belt pulleys, is not desirable at other times. The pulley, extending beyond the frame, is liable to catch on obstructions, such as gate posts when passing through gates, which may result seriously, even to bending the pulley shaft. The season for using the pulley is a limited one and it usually comes all at one time. The rest of the time the pulley is an incumbrance, as stated above. Why not make the pulley readily detachable and as readily reattachable in only the correct way? This would overcome the disadvantage cited here to placing the pulley outside of the frame of the tractor.

Flexibility

By "flexibility" is meant a design of frame which will enable two of the wheels to oscillate about a common horizontal longitudinal axis in such a way that all four wheels can remain on the ground when moving over rough ground or drainage ditches without in any way warping the frame of the tractor. This is necessary to assure ease of operation and long life, and to make the tractor as light in weight as possible, for, if sufficient flexibility is not provided the frame of the tractor must be made sufficiently strong to overcome the warping tendency when the tractor moves over rough ground or farm ditches, and therefore heavier, or the motor, transmission, etc., will be thrown out of alignment which will reduce the life of the tractor.

Wheels

Tractors should be equipped with as large wheels as is practically possible. Small wheels make it difficult to pass over rough ground and drainage ditches without danger of stalling the tractor, and frequently tractors are stalled because of the small wheels. Furthermore, considerably more power is consumed in propelling a tractor with small wheels than there would be to propel the same tractor with larger wheels.

Springs

Spring mountings are very desirable and should be used to as great an extent as is possible without, however, tending to make the tractor more complicated and therefore increasing the cost of maintenance. Simplicity of design with springs tends to reduce the wear and tear on a tractor and very considerably increases the comfort of the operator.

Weight

Labor and material are expensive. Therefore the tractor should be built as light in weight as is consistent with proper strength and proper traction. Only sufficient weight is necessary to cause the lugs to penetrate the soil to their full depth while the tractor is at work, thus enabling it to develop its full draw-bar power. Sufficient weight, in the case of tractors having their drive wheels in the rear, should be placed over the front wheels to keep them from leaving the ground (rearing up) when the tractor is exerting its maximum draw-bar power or

when going up any incline that may reasonably be expected in the ordinary performance of its duties. While much has been done in reducing the weight of the better designed tractors it seems reasonable to expect that still more can be accomplished in the matter of weight reduction, by the use of steel alloys and other alloys in the frame and in other places without interfering with the traction or the power of the machine, and also not reducing the weight on the front wheels sufficiently to cause the tractor to rear and endanger the life of the operator under conditions cited above.

Special Attachments

"It is obviously impossible to obtain maximum results with a tractor when it is used with implements designed primarily for use with horses, and the objection of many tractor owners that the tractor cannot be used with profit for certain types of field work will probably cease to hold good with the development of special machinery for use with the tractor." This is a quotation from a statement made in both *Farmers' Bulletins No. 719* and *No. 963*, both of which have already been referred to. This merely voices the sentiment of practically every one who is giving much thought to the ultimate design of the tractor. There cannot be any question as to that. The tractor must be a complete machine and ultimately will be designed as a complete machine, attachments and all.

Power Lift

There seems to be no reason why a power lift cannot be included in the design of the complete machine whereby the attachments can be raised and lowered by means of the power of the motor on the tractor. This accessory could be made very simple and inexpensive. It would increase the cost of the complete machine but very little and that little the farmer would gladly pay for the increased convenience.

Motor Power for Attachments

Nor is there any reason why attachments requiring power for their proper manipulation cannot derive same direct from the motor on the tractor instead of having it passed from the motor, through the tractor drive wheels, then through the bull wheel of the attachment (or implement) as is now done with work animal drawn implements, such as mowers, binders, etc. The motor supplies the power in any event, then why not by the most direct and least power-consuming way? The International Harvester Company has recently recognized the desirability of this feature by bringing out one model of their tractors which has a connection to supply power to one of its implements direct from the motor. This accessory could also be made simple and inexpensive. It would not be necessary to equip it with a variable speed transmission. Extra sets of gears, or extra sets of sprockets, could be provided, should more than one speed be found necessary.

In the case of harvesting implements, such as mowers and binders, the supplying of power from the motor direct to the cutter-bar would be of distinct advantage. The cutter-bar could be operated at such a constant speed as experience has indicated produced the best results. Then the tractor could be run at a speed which would, as nearly as possible, feed the crop to the cutter-bar at its full capacity. The running of the cutter-bar at constant speed and the tractor at a variable speed while harvesting is made possible through equipping the tractor with more than one speed in reverse.

Fool-Proof

Tractors are not infrequently placed in the hands of unskilled and even ignorant labor. Therefore it is positively essential to make them as "fool-proof" as possible. All gearing should be housed to prevent accident if it has not already been done to permit efficient lubrication and to reduce the wear and the power required to move the tractor. The manipulation of the tractor should be made as simple and as easy as possible, and also if possible in only the correct way. Attention to all of these points will increase the efficiency of the operator and enable him to accomplish more work with the tractor in a given time, thus again reducing the cost of the work. An interlocking arrangement is desirable which will prevent the operator from getting two sets of gears in mesh at the same time, with the consequent damage to the tractor. I haven't the slightest doubt that the farmer will gladly pay any reasonable additional cost necessary to make the tractor as "fool-proof" as possible, for he would be repaid many times over that additional cost in the saving effected thereby in performing the work the tractor was acquired for.

Summary

Therefore the query, "What form will the tractor ultimately take?" may be very largely answered by stating that it will be the form of those tractors which will embody the features which will enable the general farmer to do all of the work on his farm which he is now doing with work animals and portable engines, and do it in a more economical and efficient manner.

Just before going to press word was received that the next A. S. A. E. meeting would be in the Crystal Room, Hotel Sherman, Chicago. Although not definitely decided, a banquet is being planned for the evening of the second day's session. For various reasons there was no banquet at either of the last two meetings. A number of the members regretted this fact and the Committee on Local Arrangements desiring to please the majority of the members has asked that all suggestions be sent to Mr. W. G. Kaiser, chairman of the committee on local arrangements, 1537 Conway Bldg., Chicago.

NEW MEMBERS

C. A. Johnson, sales engineer, Hyatt Roller Bearing Co., Muncie, Indiana.

Thomas Roy Jones, assistant works manager, Moline Plow Co., Rock Island, Illinois.

Charles B. Rose, works manager, Universal Tractor Moline Plow Co., Moline, Illinois.

Harold G. Wilson, ass't sales manager, Hyatt Roller Bearing Co., Chicago.

Edward Philip Stahl, sales engineer, Hyatt Roller Bearing Co., New York City.

Otto W. Young, engineering manager, Tractor Bearings Division, Hyatt Roller Bearing Co., Chicago, Ill.

Philip Norton Overman, sales engineer, Hyatt Roller Bearing Co., Chicago.

Harry E. Roethe, ass't in grain dust explosion prevention. U. S. Dept. of Agriculture, Bureau of Chemistry, Washington, D. C.

Philip Haxall Noland, sales manager, Power Machinery Dept., Moline Plow Co., Moline, Illinois.

Alva Esmond Brandt, instructor in farm mechanics, Oregon Agricultural College, Corvallis, Oregon.

George A. Bancroft, ass't superintendent, Thresher Works, Advance Rumely, La Porte, Indiana.

Paul W. Stankee, designer, Gordon-Van Tine Co., proprietor Stankee Steel Specialty Works, Davenport, Iowa.

Amada J. Knapp, inspector, Advance-Rumely Company, La Porte, Indiana.

Major Richard B. Hewitt, fire protection specialist, Birmingham, Mich.

C. J. Hood, superintendent, Advance-Rumely Company, Thrsher Works, La Porte, Indiana.

Miles S. Potter, plant executive, Waterloo Gasoline Engine Company, Waterloo, Iowa.

Joseph F. Gauger, ass't district sales manager, Cleveland Tractor Company, Chicago.

Reuben Kuempel, Engineering Dept., Tractor Bearings Division, Hyatt Roller Bearing Company, Chicago.

Albert B. Welty, mechanical engineer, Emerson-Brantingham, Rockford, Ill.

John Parliaman French, supt. of construction, E. B. Berman Iron & Metal Co., Alma, Michigan.

APPLICATIONS FOR MEMBERSHIP

All members are asked to promptly send all pertinent information, concerning the applicants, to the Secretary's office in order that it may be brought to the attention of the Council prior to the applicants' election.

Guy Browning Arthur, general sales and advertising manager, Waterloo Construction Machinery Co., Waterloo, Iowa.

Sylavanus Dyer Locke, vice president and treasurer, Locke Steel Chain Co., Bridgeport, Conn.

Ward R. McGanen, McGanen Tractor Co., Missouri Valley, Iowa.

Wm. Webber, designer of harvesting machines, Mc Cormick Works of International Harvester Co., La Grange, Illinois.

Clinton A. Hagadone, designer, International Harvester Co., Western Springs, Illinois.

Arthur Francis Graham, Jr., experimental engineer on spry wheel, H. C. Dodge, Inc., Newtonville, Mass.

Wyatt Arnton Clegg, associate professor of agricultural engineering, Georgia State College, Athens, Ga.

Edward Hall Kimbark, assisting supervising design, International Harvester Company, Chicago, Ill.

B. R. Benjamin, supt. of experiments, International Harvester Co., Oak Park, Ill.

Harvey B. Heider, mechanical engineer, Luce Sugar Cane Harvester Co., Watertown, Wis.

Samuel K. Dennis, supt. of experiments, International Harvester Co., Chicago, Ill.

Will Huddle, designer, International Harvester Co., Chicago, Ill.

J. R. Bateman, sales engineer, Hyatt Roller Bearing Co., Chicago, Ill.

Robert Leon McKnight, agricultural representative, Hercules Powder Co., Memphis, Tennessee.

Ralph L. Ford, assistant superintendent experiments, West Pullman Works of International Harvester Co., Chicago, Ill.

James A. Moxey, supt. of experiments, International Harvester Co., Chicago, Ill.

Edward Mowry, supt. of experimental dept., International Harvester Co., Rock Falls, Ill.

Priestly Howard Williams, salesman, Hercules Powder Co., Memphis, Tenn.

Wm. S. Graham, sup't of experiments, International Harvester Co., Canton, Ill.

C. R. Raney, designer of agricultural machinery, International Harvester Co., Chicago, Ill.

H. A. Watson, manager, Domestic Engineering Department, Crane Co., Memphis, Tenn.

Arthur Johnson, Experimental Dept., International Harvester Co., Chicago, Ill.

Charles Pearson, designer of agricultural machinery, International Harvester Co., Chicago, Ill.

Edward S. Charles, designer, International Harvester Co., Chicago.

Amoldus S. Brumby, ass't professor agricultural engineering, A. & M. College of Mississippi.

Douglas Luther Arnold, chief engineer special engineering, International Harvester Co., Oak Park, Ill.

Wm. L. Beall, sup't of experiments, Chattanooga Plow Co., Chattanooga, Tenn.

L. J. Bohn, secretary and treasurer of Motor Institute, Inc., Minneapolis, Minn.

Claude S. Bristow, ass't chief engineer, J. I. Case Plow Works Co., Racine, Wis.

Howard Bertrand Bliss, specialist in rural engineering, Knoxville, Tenn.

Charles Littleton Fuetz, salesman, Fuetz & Keiser, Lancaster, Ohio.

Charles Floyd Crumb, designer, International Harvester Co., Chicago, Ill.

Rudolph H. Driftmier, instructor, Kansas State Agricultural College, Manhattan, Kansas.

Harold W. Ferris, sales manager & engineer, Consolidated Gas & Gasoline Engine Co., 202 Fulton St., New York City.

Arthur Fife, irrigation engineer, Utah Experiment Station of Utah Agricultural College, Logan, Utah.

Roy Burton, professor of agricultural engineering, Moscow, Idaho.

John Robert Haswell, farm mechanics extension & drainage engineer, Pennsylvania State College, State College, Penn.

Rex Benner Hitchcock, experimental engineer & harvesting machine designer, I. H. C., Chicago, Ill.

G. M. Mervin, designer of agricultural machinery, Berwyn, Ill.

Robt. M. Mitchell, designer, International Harvester Company, Chicago, Ill.

Charles W. Robinson, supt. of experiments, International Harvester Company, Chicago, Ill.

Wm. C. Shinn, president of W. C. Shinn Manufacturing Company, 14 E. Jackson Blvd., Chicago, Ill.

Frank Hazelton Smith, agricultural specialist, Roderick-Leon Mfg. Company, Newark, Ohio.

Herbert Bell Sperry, designer, International Harvester Company, Chicago, Ill.

Alex. C. Lindgren, manager plow experiments, International Harvester Company, Evanston, Ill.

Howard David MacDonald, asst. manager gas power engineering, International Harvester Company, Riverside, Illinois.

Oliver Brunner Zimmerman, engineer, International Harvester Company, LeGrange, Illinois.

Francis Kildare Flynn, chief engineer, Luce Sugar Cane Harvester Company, Watertown, Wis.

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